BOWLDERS OF CHAMPAIGN COUNTY

AND

WHAT THEY TEACH.

BY

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INTRODUCTION.

In the treatment of this subject, "The Bowlders of Champaign County, and what They Teach", we shall give a brief account of their distribution; reasons for their presence; and a classification of the specimens collected. We then treat briefly of their origin, metaphorphism and decomposition; and of peculiar forms of rocks, roundness, smoothness etc. Veining, a very noticeable feature will be treated of quite fully. In this description we shall refer to those of our specimens which illustrate the points in question, by the section and number under which they may be found in the Museum.

COLLECTION OF SPECIMENS, HOW MADE.

The collection of specimens from which the data was secured for this thesis, and which is now in the geological department of the museum of the University of Illinois, was made during the summer of '91. To visit every part of the county in the time that could be given to such work, was impracticable, hence, to get the best idea of their distribution, and to make the best representative collection, we traveled in parallel lines from east to west over the county, deviating from this general plan sufficiently to include most of the territory covered by the several moraines of the county. By means of a heavy hammer and "strike," we broke pieces from the bowlders, sufficiently large to be classified and to show the general crystallization of the rock. In cases of peculiar veining or structural formation, specimens were taken to represent these phenomena, as well as they could be represented by pieces.

DISTRIBUTION.

The distribution of the bowlders of Champaign County can be spoken of only in a general way. They are more plentiful in the south and west parts of the county, than in the north and east, and on or near moraines, than in the valleys-(the areas between moraines). They are furthermore, more numerous on the sides than on the top of a moraine, this being especially true of the side having a southern aspect. By the top of a moraine, we must be understood to include all the high lands of the ridge. The width of a moraine may vary from a few rods to several miles. The presence of more bowlders on the side of a moraine than on the top, is easily accounted for by a study of glacial action. A moraine evidently was formed by a standing glacier: consequently a great amount of material was deposited at one place, making a large pile, if we may call it such, of debris, which, if every influence could have been instantaneously removed, would have appeared as an immense ridge in an otherwise comparatively level country. But the glacier after having been stationary for a period of time, receded, depositing matter in its very slow backward movement. A glacier is said to have been standing, when the supply of ice at a single point, and the rapidity of melting equal each other. The glacier in its backward movement constantly deposited debris, hence we have the northern slope much less abrupt than the southern, which, in fact, in many cases can scarcely be recognized as a slope. Other being equal, then, the number of bowlders exposed would be greater on the side having the more abrupt slope. Again the action of surface waters would be greater on a sudden decline, and this by carrying away the finer material would expose many otherwise hidden bowlders.

A good many bowlders, though usually very small, are found in the few rivers and running streams in the county, and they are most numerous, in places where a stream runs near or through a moraine. In several instances the bed of the stream was found to be covered with them.

THE SIZE OF BOWLDERS.

Our use of the term bowlder includes all stones from one or two inches in diameter upward. The average sized bowlder is from two and one half, to four and one half feet in diameter. However, a great many very much larger ones are found. Among the noticeably large ones is that on Roughton's farm, one mile north of Rantoul, which is thirty-five feet in circumference one way, by forty-five the other; the stone being egg-shaped. It is a granite, of quite regular crystalization and smooth surface. This is really the largest bowlder, as far as we know, on the surface, in the county.

Another remarkably large one was found on a farm about ten miles south-west of Rantoul, in Condit township. This stone, when examined had been broken and hauled to a road side, but judging from the size of the piles of fragments, it must have been considerably larger than the rock above mentioned. It is a mica schist, a specimen from it may be seen in the collection in the museum.

A third, though not so remarkably large bowlder, is found one and one half miles west, and one half mile south of Seymour. The rock is peculiar in its being composed of very large crystals of quartz, feld-spar, and muscovite. It shows very strikingly the relative effects of weathering upon these three minerals. The muscovite crystals project from the rock mass in such a manner as to be easily broken out, affording exceedingly fine specimens of that mineral.

GLACIERS AND MORAINES.

In speaking of distribution, we have introduced the terms "glacier" and "moraine".

A glacier, roughly speaking, is a moving river of ice. This is applicable more especially to mountain glaciers, than to the continental forms.

Mountain glaciers have existed ever since the formation of a mountain sufficiently elevated to produce the requisites for glacial formation, namely, abundant rainfall and low temperature, and they exist today as living examples, substantiating the many theories now advanced in regard to glacial formation, movement etc. That which concerns us most was the great continental glacier of the north, in the region of Hudson Bay, whose southern projections reached far to the south, covering a good portion of eastern North America. Its southern border is roughly indicated by the 39th parallel. The glacier was heaviest and thickest in the east, thinning out towards the west and finally disappearing on the inland plains. Its formation was due to an unusual amount of rainfall, accompanied by an elevation of the surface, and consequent diminuition of temperature, producing thus an immense amount of snow and ice. It is estimated that the mass was 10,000 feet thick at Hudson Bay during the glacial or ice period, which period according to our best authorities was three times as long as that which has since elapsed.

The glacier being subservient to the same law, gravity, that governs bodies or streams of water, was set into motion in the direction of least resistance which from the nature of the surroundings, was southward. This was due first to the general slope of the continent southward, and second to the downward pressure of the mass of snow and ice that had accumulated. We cannot go into detail in speaking of glacial motion, but will say that the same laws and phenomena seen in running waters are applicable to glaciers in motion, save that a great deal more time is required to accomplish the same movements. Knowing the action of water upon soils, how it washes or carries away from one place and builds up at another, we can apply the same principles to the glacier, and comprehend how moraines are formed, and how our bowlders came to be distributed as they are throughout the county.

Previous to the ice age the beds of rock of the north, having been exposed to the action of the air, heat, waters etc., for a long period of time, were loosened and decomposed to great depths. The glacier being so deep as it was, exerted much pressure, picking up and carrying with it a great amount of this loosened material. The debris picked up by the advancing glacier, formed an almost irresistible body, which not only continued to pick up and carry with it portions of the loosened material, but greatly aided the destruction of rock masses by loosening still other parts for the oncoming ice and snow.

The glacier, having completed its southernly motion, began to recede. Its recession was caused by a gradual sinking of the continent, or a decrease of rainfall, probably by both combined. By the recession of the glacier we must be understood to mean not a movement to the north of the whole ice mass, but a melting of the southern portion of the mass, which was more rapid than the advancing movement, until the whole had disappeared. This recession gave origin to our moraines.

Moraines are of two kinds, ground and lateral or terminal. By the steady and gradual, but alternating backward and forward movement of the glacier the ground moraine was formed. The backward motion was as slow or slower perhaps than the forward, and as it receded the debris that had been carried down was deposited. The deposition in this county is between two and three hundred feet deep.

The recession of the glacier was not as might be supposed, one steady movement to the north but a to and fro motion, moving to the north and then to the south and again to the north. This backward and forward movement has made the ground moraine as it is, stratified, a bed of sand and gravel, and then a bed of clay etc. Thus too, did the glacier give rise to the strata from which our water supply is drawn.

Had the gradual melting away continued we would have had nothing but the ground moraine, but at intervals during the melting period, there were seasons of great rainfall which practically checked the recession, causing the melting to be continued at a point which was comparatively stationary. In this manner was formed the terminal moraines which in the character of their formation are just the same. These mark the last advance of the retreating glacier.

CLASSIFICATION.

One of the most difficult things in the study of Geology, is the classification of rocks, there being no dividing lines that are natural. All schemes for classification are necessarily artificial, owing to the gradual gradation of one kind of rock into another. The scheme used for this classification is a simplified method arranged by Professor Rolfe of the University of Illinois, and used by him in his classes in Geology.

We collected and classified in all, five hundred and seventy specimens of bowlders in which we found thirty-three different species, excluding several varieties not taken into account. Of these specimens a fraction over fifty per cent were granitic, of which forty specimens were granites, the remainder being granitites. The difference between the two is only in the kind of mica the specimen contains: the former containing muscovite and the latter biotite as the dominating micaceous mineral. The next largest number of any one kind found is diabase which constitutes 7 % of all the specimens collected. 20 % of these were olivine bearing.

The different kinds of rocks found are given in the table below. The kinds of rock found whose percentage amounts to 1 % or more of all the specimens named, will be designated. It is not expected however that the per cents here given are correct as to the actual amounts of the various kinds of rock in the county. The different effects of weathering action upon rocks gives to them different appearances. A homogenous fine grained or firmly cemented rock weathered, will give a greenish, glassy appearance, while a non-homogenous, coarse or loosely cemented specimen of the same rock will present a wholly different appearance, while weathered specimens of widely different species, but having the same structure, often resemble each other closely. Thus some rocks are much more easily recognized off hand than others. This naturally leads to a disproportionate collection.

CRYSTALLINE.

Name.	Per cent.
Granites	7 %
Granitites	43 "
Amphibole Granites	
Gneiss	4 "
Schists	4 "
Quartzites	5 "
Aphites	1 "
Hornblende Syenites	1 "
Mica Syenites	1 "
Augite Syenites	1 "
Trachytes	
Mica Diotites	2 "
Quartz Mica Diorites	
Porphorites	
Gabbros	1.5"
Olivine Gabbros	
Diabases	6 "
Olivine Diabases	1.5
Quartz Diabases	

FRAGMENTALS.

Name.	Per cent.
Ferruginous Sandstones	4 %
Kaolin Sandstones	
Ferruginous Conglomerates	
Silicious Conglomerates	
Slates	
Travertines	
Shell Limestones	
Argillaceous Limestones	1.5 "
Ferruginous Limestones	

A further classification may be made on the basis of the amount of silica present in the rock, those rich in silica being known as acid rocks and others poorer, though usually having some silica, as basic rocks. This classification naturally can be given only to crystalline rocks, as fragmentals, owing to the manner in which they are formed, are not so easily grouped.

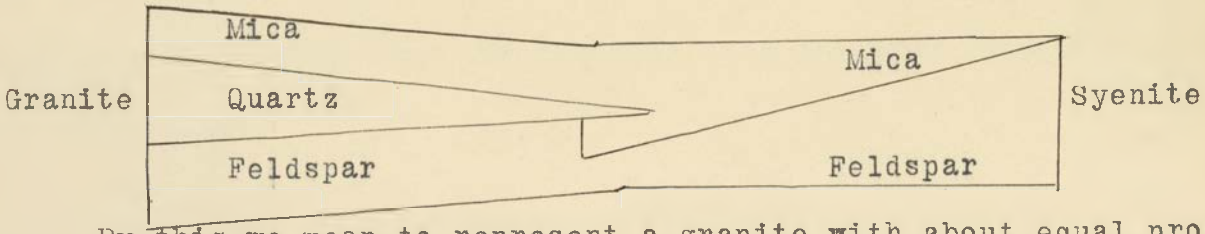
Acidic	Basic
Granite	Mica Diorite
Granitite	Quartz Mica Diorite
Hornblende Granite	Gabbro
Gneiss	Olivine Gabbro
Quartzite	Diabase
Mica Schist	Olivine Diabase
Hornblende Syenite	
Augite Syenite	

All lines of classification are naturally artificial and in specimens near or very near the bordering line, it is difficult to determine to which class they belong, and in many cases they may as properly be placed on one side of the line as the other. There is an almost imperceptible change from the one to the other. Not only is this true of crystalline rocks, but also it is true of fragmentals.

To represent this gradual gradation, and what is true of one group is true of all, we have chosen the

GRANITIC GROUP

The granitic is pre-eminently an acidic group, and yet it passes insensibly into the more basic syenites, which in turn passes in a similar manner into the diorites and diabases. Starting for example with a specimen rich in silica, it is possible to arrange a series in which there is a gradual decline in the amount of this element present, until we, reach a specimen in which quartz occurs only as an accessory, or not at all. This transition may well be illustrated by the following diagram:



By this we mean to represent a granite with about equal proportions of Mica, Quartz, and Feldspar, and from this passing through specimens constantly growing poorer in quartz, we reach finally a rock in which very little quartz is found, and later a specimen in which no quartz at all is present. We then have nothing at all remaining but feldspar - usually orthoclase- and mica and the rock is known as a mica syenite, in this either the mica or feldspar may dominate, as we have shown in the right half of the figure.

To trace the changes a little more minutely we have arranged our collection of the granitic group in such a manner that the various steps may be followed out in this passage from the one into the other. We refer to the specimens by number, -the collection has been placed upon shelves in the geological department of the museum of the University- to which reference may be made at any time, where the changes spoken of may be observed.

This series is found under section A of the collection. No.1 is a specimen almost wholly orthoclase. But on a clearage surface may be found two small but perfectly formed crystals of quartz. No.2 has more and larger crystals of quartz yet with orthoclase predominating. Similar to this are the specimens 3 & 4. No.5 is a specimen in which the quartz is greatly in excess of the feldspar present, while No.6 is a specimen in which we have the first traces of mica. On the clear-age faces of the orthoclase May be seen the first and merest traces of muscovite forming from the feldspar. The feldspar, probably is not pure orthoclase.

Nos. 7 to 11 show later stages in the developement of musco-vite from orthoclase, and show also a gradual increase in the amount of mica in the rock.

No. 12 shows the presence of both muscovite and biotite. The muscovite in the specimen is of a dark greenish color.

No. 13 - 19 show a gradual diminuition of quartz and a gradual increase of mica (biotite) until reaching No. 20 when the mica seems to decrease in quantity and finally in No.24 we have feldspar and mica present in about equal amounts with simply traces of quartz. This specimen at first sight might be easily mistaken for a syenite and really is not much different from the specimens that follow in section B.

Muscovite and biotite are the great micaceous minerals found in rocks. Cases in which muscovite exceeds in any great degree either quartz or feldspar in a granite, are of unusual occurence. However with biotite as the micaceous constituent, the above is not true. We find many specimens in which biotite is much in excess of either of the other minerals and constitutes from 60-70% of the rock mass.

-Nos. 19 & 20 section A of collection-

Granite rocks rich in biotite is the rule, but from these very rich specimens we pass downward through every proportion of biotite as compared with the other two minerals, until we finally reach a stage, which, like the case of pure granite, is mostly feldspar and quartz or perhaps feldspar alone with only here and there a crystal of biotite- No.3 of Sec. Q represents such a specimen. The same is true in the case of quartz and the feldspars. We have them in the granitic series of rocks, every conceivable variety and every possible proportion of the three granitic minerals existing between the two extremes, the acidic as the one extreme and the more basic as the other. Not only is this true of the more acidic groups but also is it true in the basic groups. Every variation is recognizable in the mineral constituents, passing from one extreme to the other, and reaching lines where it is almost impossible to distinguish between hand specimens.

ROCK FORMATION.

Rock formation may be spoken of briefly, as the nature of many specimens collected will include the question of their formation.

The terms crystalline and fragmental are used to distinguish the two great groups of rocks: The former, as ordinarily used, represents the class of rocks which had their origin in the original heated mass of the earth or in metamorphic action; the latter represents that class which has been formed from the action of water and cementing agents.

In crystalline rocks only two distinguishing features need recognition, viz., the intrusive and effusive forms. By these terms we indicate whether the rock has been formed deep down in the crust of the earth, or very near its surface. The slow cooling of the rock mass under heavy pressure gives the former, and more perfect rock. With rapid cooling and with no pressure save the weight of the mass itself, the second, effusive, forms are produced. These forms are characterized by a peculiar glassy ground mass containing crystals more or less perfectly developed, and although many thousands of years old, are said to be comparatively young. The chief difference then between a rock of an early or late formative period is that the one is more perfectly crystalline than the other.

A fragmental rock is more easily determined, owing to the roundness of its grains which are due to the erosive and abrasive action of water. Yet some fragmental rocks are purely crystalline, in consequence of metamorphic action, as in the case of marble. In this class of rocks as in the other, an immense amount of time is required for their formation.

SANDSTONES.

Section K of the collection represents a series of sandstones which are arranged according to the size of the cemented particles.

No.1 is a medium grained rock whose cement is partly ferruginous and partly calcareous.

We have already referred to the action of water in destroying one part of the earth's surface, and building up another. This is noticeable in ditches and small streams where the water in going over a rapid descent tends to wear away and wash out the bed over which it is flowing, and to deposit the material thus taken up in places more nearly level. This was the action in the formation of the rock. The water has collected the sand grains from various places in its course, and has deposited them at some lower level. But aside from this mechanical work that the water has done, it carried with it in solution a great amount of cementing material, which being percipitated in the gravel and sand beds thus formed, firmly united the particles into a hard stone. The specimens which follow, Nos. 2-21 are formed in the same way and are arranged according to the size of the sand grains. All of these specimens are cemented by a ferruginous substance which varies largely in amount. The dark color of some of them is due to the excessive amount of iron they contain.

No.3 has embedded in its mass a few crystals of iron pyrites which are crystals carried in by water.

No. 22 is a kaolin sandstone, formed by the decomposition of feldspar in the sandstone.

No. 23 is a sandstone of fine grains but whose cementing material is purely calcareous.

The size of the particles present in a sandstone, vary greatly. There can be no definite line drawn between the sandstones and conglomerates, which are formed in the same way as sandstones are formed. But supposing the sand grains of a specimen to be as large as peas, we then will have every size from that down to a rock whose constituent particles can be recognized only by means of a compound microscope. No. 22 of our collection represents a specimen of such a sandstone.

The origin of the different sandstones is easily understood from the law of gravity. A small particle will be carried by the water a great deal farther than a large one. Hence water in its course, providing its motion remains uniform, deposits its washings according to the size of the particle, the largest being deposited first, and the smallest carried the farthest.

The large pebbles and pieces of rock thus collected and cemented give rise to

CONGLOMERATES.

No.1-3 Sec. Q. are specimens of conglomerates. Nos.1&2 are from the same rock. The pebbles here are of quartz and ferruginous sandstones that have been collected and cemented together by a silicious cement.

Similar to these is No.3, but its parts are much larger, and have been united by means of a ferruginous cement. Really it is a bed of quite large pieces of rock around which or in which a sandstone of finer grains has been formed, the sandstone acting as a cementing agent to the larger parts.

LIMESTONES.

In Sec. L of our collection we have a few specimens of limestone collected from the county. The number of limestone bowlders, as far as known in the county, exposed on the surface are few but along ditches and in creek beds many small pieces of limestone may be found.

In the northwest part of the county are several limestone deposits which are of particular interest. The deposits were accidentally found by ditchers under the employ of Mr. Benjamin Gifford. Only one of these deposits was quarried. This yielded three carloads and over a hundred wagon loads of stone. The deposit seemed to be one immense bowlder that was carried down by the glacier. Its composition is calcium, clay and a little magnesia. The stone thus quarried has been used for building purposes but surely will not be lasting.

There is a fine variation in limestones, something like that we attempted to follow out in our granitic group of rocks. The most of the specimens are argillaceous. No.1 however, has considerable magnesia in its mass.

The formation of limestone is due to two general, and a variety of specific causes. The deposition of silt, of carbonates and the remains of various animals are among the more prominent.

METAMORPHISM.

If we were to select any one branch of geological study, that was more difficult than any other, more complicated in its workings, one with which a student feels less satisfied with his results, we would say it is Metamorphism.

Metamorphism is almost universally recognizable. In nearly every kind of rock; in every position, and every place do we find metamorphic changes at work. The term metamorphism must not be understood to mean anything other than changes wholly within the rock itself. The form of the rock is supposed to remain the same and in many cases minerals that have been subjected to metamorphic action, have not lost the form of the original mineral. For instance the change of a hornblendic mineral to jasper-(Mauer)- or of cinolite to augite-(Rammersberg)-. However, a great many minerals thus acted upon wholly lose their identity.

DOLOMITE.

The simplest form of metamorphism as shown in rocks, is that of dolomitization or the change of a limestone which is almost wholly a calcium carbonate to one rich in magnesia (a dolomite is a limestone containing 50-60% magnesia). Two different theories are advanced in explanation of this change. The first theory, and the one supported by the best school of geologists of today, is that the limestone being once deposited in whatever way, is acted upon by waters containing a great amount of carbonate of magnesia, and that this water in passing through the limestone beds takes up the less stable calcium carbonate and leaves behind the more stable magnesium carbonate. This is in accordance with the replacement theory of vein formation, and in its action is identical.

The second theory is that both calcium and magnesium carbonates have been deposited simultaneously, and that the calcium carbonate afterwards was removed by infiltrating waters. This theory, if indeed it can be called a theory, does not receive any great amount of geological support.

A very striking example of the action of waters impregnated with mineral constituents, is a specimen found, which has every indication of having once been a limestone, but having been flooded with waters strongly saturated with other mineral elements, has given up its calcium in exchange for the other substances. The materials thus left behind have crystallized into beautiful garnets. The garnets are small, scarcely recognizable by the naked eye but by means of a simple microscope many beautiful crystals are discernable.

In a similar way must have been formed the beautiful garnets in a gneiss bowlder found on a farm one and one half miles south and three fourths of a mile west of Gifford. In this rock the crystals are much larger and are seen in their perfect form by the naked eye. The garnets in this rock,are rather evenly distributed and average about four or five to the square inch of surface. The specimen is found in section P. No.1.

ALTERATION AND DECOMPOSITION PRODUCTS.

In speaking of alteration or decomposition products we aim to touch only those minerals which occur most prominently as constituents of bowlders found in the county. The products are not wholly or satisfactorily worked out, but enough has been gained to show in a general way the main features connected with such changes.

FELDSPAR.

With the exception perhaps of quartz, feldspar is the most universal rock constituent. It forms one of the characteristic minerals of many rocks, and is found as an accessory in many others.

The alteration of feldspars is effected through the infiltration of waters charged with acids which were formed by the decomposition of sulphids, sulphates, carbonates,&c, or of waters containing alkalies or other solvents.

The first signs of decomposing feldspar as given by our author, is the formation of mica or garnet upon cleavage surfaces.-For an illustration of feldspar changing to mica see collection, Sec.A.Nos.5-11. When the infiltrating water contains carbolic acid, the feldspar acted on first loses its lime, if a lime feldspar, by the combination of calcium with the carbonic acid. Next if any carbonic acid remains, the alkalies are taken up as carbonates and removed,or in the absence of any more acid, they are removed as silicates. The changes thus going on finally end in the production of kaolin, which is a hydrous silicate of alumina.

Orthoclase, $\dddot{\cancel{\mathrm{Al}}}\ \ddot{\mathrm{Si}}_3 + \dot{\cancel{\mathrm{K}}}\ \ddot{\mathrm{Si}}_3$ gives rise (before forming kaolin) to muscovite, $3\dddot{\cancel{\mathrm{Al}}}\ \ddot{\mathrm{Si}} + \dot{\cancel{\mathrm{K}}}\ \ddot{\mathrm{Si}}$.

We give the alteration products of orthoclase and Albite as given by Dana, with their chemical formulae.

Orthoclase $\dddot{\cancel{\mathrm{Al}}}\ \ddot{\mathrm{Si}}_3 + \dot{\cancel{\mathrm{K}}}\ \ddot{\mathrm{Si}}_3$
Albite $\dddot{\cancel{\mathrm{Al}}}\ \ddot{\mathrm{Si}}_3 + \dot{\cancel{\mathrm{Na}}}\ \ddot{\mathrm{Si}}_3$

Steatite } $\acute{Mg}_3\,\ddot{Si}_4 + \dot{H}$
Talc }
Chlorite $2\dot{R}\,\ddot{Si} + \acute{R}_2\,\dddot{Al} + 3\dot{H}$
Kaolin $\dddot{Al}\,\ddot{Si}_2 + 2\dot{H}$
Lithomarge (Kaolinic substances)
Muscovite $3\dddot{Al}\,\ddot{Si} + \dot{K}\,\ddot{Si}$
Laumonite $\dddot{Al}\,\ddot{Si}_3 + \dot{Ca}\,\ddot{Si} + 4\dot{H}$

The change from feldspar to kaolin has already been given. In the case of steatite and talc as products from feldspar there is some question. The feldspars however, are probably acted upon by waters strongly impregnated with potassium and magnesia. The potassium uniting with the alumina gives rise to potassium aluminate and by leaving the magnesia behind the resulting product will be steatite or talc.

To anyone at all acquainted with chemistry, it is evident that orthoclase or albite may give rise to the other products named in the list. It is held, however, by some authors that kaolin is the final product of all feldspars.

From Dana, we have the following as products of

ANORTHITE.

Anorthite $\dddot{Al}\,\ddot{Si} + \dot{Ca}\,\ddot{Si}$
Linseite $\dddot{Al}\,\dddot{Si} + (\dot{Fe}\,\dot{Mg})_2\,\ddot{Si}_2$
Sundvikite $\dddot{Al}\,\ddot{Si} + (\dot{Fe}\,\dot{Mg}\,\dot{Ca}\,\dot{Na})_2\,\ddot{Si}_4$

These changes evidently are wrought by the passing of waters rich in the bases, which are left behind as the waters pass through.

MICAS.

The micas hold a very prominent place in the mineral constituents of rocks, but less so than do the feldspars. Black Mica, (biotite) is especially abundant, and quite prominent in granitic rocks.

Muscovite is less common among the Champaign County bowlders. The direct decomposition of muscovite is kaolin. Dana gives as other products, steatite and serpentine. Biotite results in Rubellan and steatite through alteration.

$$\text{Muscovite} \quad 3\dddot{\cancel{\text{Al}}}\,\ddot{\text{Si}} + \dot{\cancel{\text{K}}}\,\ddot{\text{Si}}$$
$$\text{Kaolin} \quad \dddot{\cancel{\text{Al}}}\,\ddot{\text{Si}} + 2\dot{\cancel{\text{H}}}$$
$$\text{Steatite} \quad \dot{\text{Mg}}_3\,\ddot{\text{Si}}_4 + \dot{\cancel{\text{H}}}$$
$$\text{Serpentine} \quad 2\dot{\text{Mg}}\,\ddot{\text{Si}} + \dot{\text{Mg}}\,\dot{\cancel{\text{H}}}_3$$
$$\text{Biotite} \quad \dddot{\cancel{\text{Al}}}_2\,\ddot{\text{Si}}_3 + (\dot{\text{Mg}}\,\dot{\cancel{\text{K}}}\,\dot{\text{Fe}})_2\,\ddot{\text{Si}}_3$$
$$\text{Rubellan}$$
$$\text{Steatite} \quad \dot{\text{Mg}}_3\,\ddot{\text{Si}}_4 + \dot{\cancel{\text{H}}}$$

HORNBLENDES.

A very plentiful mineral, and one which causes a great deal of dissatisfaction in classification, is hornblende. The hornblendes and pyroxenes are so nearly alike in their composition, and agree so nearly in their decomposition products, that they are given by some authors as the same. Most authors give to each the same decomposition products.

Again many authors wish to distinguish between hornblende and augite, and yet not a few hold that they are the same.

Bischof treats them as entirely separate, saying however that in their behavior towards reagents, and as regards their decomposition products they are the same.

The occurence of pyroxene, hornblende and augite is quite universal in basic rocks. They are usually dark colored, and the rocks in which they are found are always dark and sometimes quite black.

Augite $(\dot{Ca}\ \dot{Mg}\ \dot{Fe})\ \ddot{Si}$

Asbestos $2\dot{Mg}\ \ddot{Si} + \dot{Ca}\ \ddot{Si}$

Serpentine $2\dot{Mg}\ \ddot{Si} + \dot{Mg}\ \bar{H}$

Steatite $\dot{Mg}_3\ \ddot{Si}_4 + \dot{\bar{H}}$

Opal (3 to 9) $\ddot{Si}\ \dot{\bar{H}}$

Braunite $(\dot{Mn},\ \ddot{Mn})_2\ \ddot{Si}$

Biotite $\dddot{\bar{Al}}\ \ddot{Si} + (\dot{Mg}\ \dot{\bar{K}}\ \dot{Fe})\ \ddot{Si}_3$

Garnet $\dot{R}_3\ \ddot{Si}_2 + \dddot{\bar{R}}\ \ddot{Si}$

It is held by some that hornblende is a decomposition product of augite, and one author has called a decomposition product of augite uralite, and describes it as having the cleavage faces and the form of hornblende. He furthermore says that uralite is formed from augite by the substitution of magnesia for lime which is exactly the way another describes the formation of hornblende from augite. The true fact is probably not known, however, most prefer to distinguish between the three in which case they say that the steps probably are Augite, Hornblende, Uralite.

Augite gives rise to asbestos by the separation of magnetic oxide of iron. The first indication of its formation is its alteration of the color, lustre and transparency with a thin coating of asbestos on the surface. Finally the whole is converted into a silky bunch of of asbestos, and at the same time the form is wholly lost. The process involves the elimination of lime, and the introduction of magnesia. Similar to this is the formation of serpentine from augite. The chief difference is that when serpentine is formed the lime has been wholly replaced by magnesia. The same may be said in the formation of Steatite.

Opal is a production in which all the bases of augite have been wholly removed.

Its conversion into braunite involves the loss of most of the silica, all the magnesia, and a small percentage of calcium, with the introduction of oxides of manganese, and of iron.

The steps from augite to mica are not definitely known.

The products of hornblende,and the modes of alteration are so nearly like those of augite, that we will not recount them here.

OLIVINE.$(\dot{Fe}\ \dot{Mg})_2\ \ddot{Si}$

One more of the common minerals found in rocks remains to be considered, i.e., olivine. The mineral is recognized by its greenish yellow color and by its hardness.

Its alteration is produced chiefly through the oxydation of its iron. Steatite and other magnesian products are the results of its decomposition.

EXTERNAL APPEARANCE OF BOWLDERS.

All rocks, crystalline or otherwise, owe their stability to the cohesive force of cementing agents. The cements common among rocks are the ferruginous, calcareous, and silicious. The action of carbonic and other acids upon these cements will in time so completely transform them that their cohesive force will be lost, and as a result of this action the rocks will crumble and fall to pieces very easily. In section N, Nos. 1--10, we have specimens illustrating the action of this acid upon the cement of the rocks. Specimen No.5 represents a stage very near final falling away. A piece of it rubbed in the hands will separate into its constituent minerals, giving beautiful crystals of quartz, feldspar and mica. Specimen No.8 of the same section shows an unequal action of the destroying agent, and the rock tends to separate into parts, but not according to the mineral division. It simply breaks into pieces each of which will contain quartz, feldspar and mica. The other specimens of this same section represent cement decay in various stages.

One of the most noticeable things about a bowlder is its comparative

ROUNDNESS.

Every one knows that a quarried or broken stone does not present a rounded surface, but that the faces are more or less angular, bounded by sharp, rough edges which meet in very prominent rough corners or angles. These characteristics are seldom found in a perfect bowlder. The action of Corrasion is always from the outside towards the centre. It tends to destroy the cement near the exposed surfaces of the rocks first, and equally towards the centre from all sides. This action then would tend to loosen corners and projections, and were the rock acted upon by no other agents it would in time become comparatively rounded. Specimens dug from the earth, which have been acted upon, in situ, by decomposing agents, give, when deprived of the loosened material, a surprisingly rounded appearance. But most of our bowlders have been acted upon by other forces.

Water, the greatest of all geological agents, has aided much in making the bowlders what they are, either by its own force, or by its abrasive action triturating one rock against another, it has hastened the decay and the wearing away of rough corners, thus producing the rounded form.

In general, it may be said of water, that it has been the chief agent in rock making, in shaping mountains, and in excavating valleys. As regards mechanical and chemical work in the geological world, it is the most universal and by far the most important factor.

SMOOTHNESS.

Smoothness is another characteristic found in an ordinary bowlder. This varies greatly, for while a rock may be rounded, it by no means always has a smooth surface. The variation is from extreme roughness through many intermediate grades to a rock whose surface is almost like glass. This difference is due largely to the character of the minerals of which it is composed. We should never expect to find a smooth, glassy rock among the coarsely crystallized varieties. The coarseness of the crystals and the difference degrees of resistance to weathering, which are known to exist between mica, quartz and feldspar, for instance, would permit of no such action. On the other hand, it is quite natural and reasonable to expect that a rock whose crystals are very small, and in which one mineral largely predominates, (as in some diabases), that we may have a smooth, glassy surface, because the action is more nearly uniform over the whole of its surface.

ROCK VEINING.

A very noticeable and common thing among the bowlders is the presence of veins. Almost every description of veining is recognizable. We have arranged a section in our collection to represent some of these. In section M will be found a specimen containing a characteristic cross vein. The one vein forms with the other almost a right angle. The substance forming the veins is mostly feldspar, with a little quartz. The specimen was taken from a rock which sometime in its history was subjected to a great disturbance, causing fissures or faults. Here then were lines of weakness, openings, towards which the subterranean waters tended to flow. These waters, highly impregnated with mineral substances, evaporated as soon as the surface of the rock at the openings were reached, leaving behind the substance which they had carried or the mineral was thrown down by some precipitating agent. Thus were begun depositions upon the walls of the rock which continued until the fissure was completely filled.

No.2 of this same section is a representative of a rock whose fissures were formed by contraction from the cooling of the rock mass in its original magma. The fissures thus formed were filled in the same manner as the fissures of No.1, which were formed by fracture. The veins in this case have been filled with quartz, olivine, and feldspar, quartz being largely in excess.

No.3 is a specimen whose vein is composed mostly of orthoclase crystals.

No.4 is a granitite containing a partially filled fissure. The rock was at some time fractured, the opening thus formed extending down, deep into regions of intense heat. The water in this place being very hot and carrying a large amount of olivine and quartz, on reaching the opening which was of low pressure, ascended, carrying with it the mineral matter which it held in solution. On reaching a higher, cooler plane, the water evaporated leaving behind the minerals which have only partially filled the opening. The quartz here is partially, but not perfectly, crystallized.

No.5 is a simple specimen taken from a vein. The vein is two inches thick and is almost pure quartz. On one side of the piece may be seen the kind of rock from which it was broken.

No.6 has a vein formed in the same manner as that of No.4. However, the fissure here is completely filled with olivine, making thus a completed vein.

No.9 is a piece of rock very rich in mica. The vein in it is quartz and feldspar. It is peculiar in the form or manner in which it has been eroded. The mass of the rock has been worn away much more rapidly than has the vein in it, the latter projecting as a sort of rib from the eroded surface. We observed in our collecting, bowlders through which veins extended, that were greatly worn away on either side of the vein, leaving it as a flat stone sandwiched between the two halves of the bowlder.

No.8 represents yet another kind of vein formation. The original rock in this case had a line of mineral weakness through which water percolated very freely. The water thus passing through having a greater affinity for the mineral lying in the line than for the mineral which it carried in solution, deposited the latter, carrying with it the original mineral in that line. This gives rise to what geologists call a replacement vein.

Other specimens in this collection represent the simplest kind of veining, and all will fall under one of the three heads just referred to.

We have touched only very briefly the many things that might be learned from the study of bowlders. Geology, in its study, is like a spreading tree. We start with a single stalk, the trunk, but soon we have dividing branches which again divide and subdivide, affording thus a thousand avenues into which one may enter, and gain knowledge from a careful study of what it offers.

Surely GEOLOGY has its important place in scientific studies.